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Eutrophication of Lakes Huhmarjärvi and Tervalampi

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Bachelor of Engineering
Degree Programme in Environmental Engineering

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Date: 30.05.2016

Author(s) Title Number of Pages Date	Sanchit Bista Eutrophication of Lakes Huhmarjärvi and Tervalampi 50 30.05.2016
Degree	Bachelor of Engineering
Degree Programme	Bachelor´s in Environmental Engineering
Specialization option	Water Analysis
Instructor(s)	Kaj Lindedahl, Senior Lecturer Johanna Korteasalmi(Lab Instructor) Marja-Leena Åkerman (Lab Engineer)

Huhmarjärvi and Tervalampi are two lakes situated in the Siuntionjoki Catchment area, Finland. These lakes are shallow and are surrounded by summer cottages and agricultural lands. The agricultural runoffs flow into the lake, and this has resulted in an excessive growth of the vegetation in the lakes. Fishing, swimming and recreational activities are not possible in some parts of the lakes due to eutrophication.

The aim of this project was to analyze the chemical content of the lake water and to determine the concentration of parameters responsible for eutrophication in these lakes. The sample water was tested in the Environmental Engineering Laboratory of Metropolia UAS using various analysis kits for each parameter. The results show that the concentration of phosphorous has increased sharply in both lakes.

In conclusion, it was discovered that the water in these lakes is nutrient enriched and unsuitable for aquatic animals. The excessive growth of vegetation prohibits swimming and even boating in some areas.

Keywords	Huhmarjärvi, Tervalampi, eutrophication, water analysis

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ABBREVIATIONS

ATP = Adenosine tri-phosphate

ADP = Adenosine di-phosphate

DNA = Deoxyribonucleic acid

RNA = Ribonucleic acid

SYMBOLS

NH_4^+ = Ammonium ion

NO_2^- = Nitrate ion

H^+ = Hydrogen ion

H_2O = Water

NO_3^- = Nitrite ion

$C_6H_{12}O_6$ = Glucose

H_2PO_4- = Hydrogen phosphate

$FePO_4$ = Ferric phosphate

$CaPO_4$ = Calcium phosphate

($(NH_2)_2CO$) = Urea

Mg/l = Milligram per liter

µg/l = Microgram per liter

P = Phosphorus

N = Nitrogen

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1 INTRODUCTION

Freshwater environments are ubiquitous and critical to humans for example, as source of drinking water, as conduits for waste materials,and aesthetical and recreational purposes. The great diversity in the form and function of freshwater system results in significant differences in microbial community structure and processes. Water flow, water depth, light level, nutrient inputs, pH, plant communities, and numerous other factors all influence the microbial ecology of freshwater (aquatic) ecosystems. (Leff, 2009)

Huhmarjärvi and Tervalampi are two lakes located in Siuntionjoki catchment area in Southern Finland. Eutrophication has been a major issue in both of the lakes. This has been a major concern to the residents residing near the lake as it hinders their recreational activities such as fishing and boating.

1.1 Huhmarjärvi

Huhmarjärvi is a small shallow lake in the Siuntionjoki main catchment area in Uudenmaan maakunta. It has a surface area of 37,23 ha. There has not been any official depth sounding. The catchment area of 8440 ha consists of mainly forests, agricultural fields, and some cottages. The lake’s beaches are somewhat steep and rocky.

The water quality of Huhmarjärvi has been being monitored since 1990’s.The oxygen level with respect to the lake’s area has been at a good level. The nutrient concentration in the lake is high and increasing. As the lake is shallow, the nutrient upload to the lake by forestry, agricultural activities, and human inhabitation causes the lush. (Länsi-Uudenmaan vesi ja ympäristö ry)

Figure 1: Lake Huhmarjärvi (Niinimäki & Niinimäki, 2011)

1.2 Tervalampi

Tervalampi is a small shallow lake in the Siuntionjoki main catchment area in Uudenmaan maakunta. It has a surface area of 41,1 ha. There has not been any official depth sounding. The catchment area of 8050 ha consists of mainly forests, agricultural fields, and some cottages. Tervalampi shore is low-lying arable land with some rugged cliffs.The lake receives diffused pollution from agriculture and forestry, and human settlements. (Länsi-Uudenmaan vesi ja ympäristö ry)

This thesis was mainly focused in analyzing the present lake situation and comparing it with its past results. This paper mainly deals with the eutrophication issues and identifies some of the factors, finding a proper solution so as to acquire a healthy eco-system to Siuntionjoki catchment area, i.e. Huhmarjärvi and Tervalampi, respectively.

Figure 2: Lake Tervalampi (Niinimäki & Niinimäki, 2011)

Figure 3: Lake Huhmarjärvi and Tervalampi. (Lehtoranta & Broman, 2011)

1.3 Objectives

The main objectives of the project were as follows:

- To identify some of the factors responsible for the eutrophication phenomenon in the lake
- To define the sampling locations and parameters to analyze the present situation of the lake
- To analyze selected chemical contents of the lake

1.4 Background

In recent years, eutrophication has been a major ecological problem in lakes. Excessive increase in water vegetation has disturbed the aquatic eco-system. Massive growth of vegetation has disturbed the use of the lake for recreational purposes.

2 LITERATURE REVIEW

2.1 Eutrophication

Natural waters acquire their chemical characteristics by dissolution and by chemical reactions with solids, liquids, and gases with which they have come in contact during the various steps of the hydrological cycle.

Eutrophication is a natural process of providing a body of water with the nutrients for the aquatic life it supports. The input of excess amounts of nutrients such as phosphates, nitrogen compounds and/or other different kinds of nutrients cause eutrophication.

A lake starts its life as a clear body of water. When the nutrient from the land run off enters the lake, aquatic life thrives and ultimately dies adding up higher amounts of organic debris. As the process continues, the debris fills up completely forming marshes followed by dried land.

The constant production, decomposition, and sedimentation of biomass caused by adding up of the excess nutrients from the run offs (mostly from the agricultural land) causes burden on underground aquifers.(Yen, 1999)

2.1.1 Causes of eutrophication

Human activities are the major cause of eutrophication. People use a lot of fertilizers on their farms, lawns, and other fields. When it rains, these fertilizers run off in to the streams and lakes and feed the hungry algae and planktons with nutrients.

Natural events also cause eutrophication. The rain and floods wash away excess of nutrients from the land and dumps it into the water bodies. However, eutrophication most likely happens nearby fertilized lands.

2.1.2 Consequences of eutrophication

Some of the main consequences of eutrophication are as follows:

- Algal bloom
- Increased vegetation may impede water flow and the movement of boats.
- The water may become unsuitable for drinking even after treatment.
- The amenity value of the water decreases (e.g. unsuitable for water sports).
- Fish population decreases.
- Turbidity increases.

When water is enriched with nutrients and silt from the agricultural run offs, different kinds of algae bloom on it rapidly. The algal bloom not only deteriorates the quality of the water but also disrupts the whole aquatic ecosystem by consuming most of the oxygen in the water leaving not much for aquatic organisms like fish. Ultimately, the aquatic organisms die. If the algal bloom is so bad, the dead organisms will sink to the bottom and decompose using the oxygen from water.

Algal blooms also block the sunlight preventing photosynthesis of plants under water surface.

The lack of oxygen from the decomposition of dead organisms and photosynthesis causes the water to be hypoxic. No organisms can survive in a bad hypoxic environment and thus, a dead zone is created.

Some algae produce toxins that have harmful effects on other forms of life resulting in adverse ecosystem.

2.2 The Nitrogen Cycle

2.2.1 Nitrogen

Nitrogen is a chemical element with atomic number 7 and symbol N.Nitrogen is a vital component for every single living being to create various complex natural particles like amino acids, proteins, nucleic acids, and numerous bio chemicals. Atmosphere is the ultimate store for nitrogen. Approximately 78% of our atmosphere is made up of Nitrogen. Nitrogen is also distributed in soil/groundwater and biomass. Microbial and plant growth is commonly limited by a low supply of Nitrogen. Despite the abundance of nitrogen in different pools, plant productivity is constrained by the lack of accessible biochemically usable nitrogen. (Harrison, 2003) (Schaechter, 2012)

2.2.2 Nitrogen compounds

Nitrogen is present as both organic and inorganic compounds in the ecosystem. Inorganic nitrogen is found in several oxidation states, from -3 in the most reduced form (ammonium) to +5 in the most oxidized compound (nitrate). However, in organic compounds, nitrogen is usually found in the fully reduced state as amino groups. The uptake of nitrogen by plants is possible only in the form of ammonium ion (NH_4^+), nitrate ion (NO_3^-) ordinarily known as amino acids. Ammonia, oftenly is processed further to make urea and ammonium nitrate to use as fertilizer.The exchange of nitrogen in between these sources is called nitrogen cycle. (Schaechter, 2012)

2.2.3 Role of Nitrogen in plants and animals

Plants need usable nitrogen for their growth and they acquire it from the soil and/or water they live. Nitrogen is the key component of chlorophyll, which facilitates the photosynthesis process in plants. It is a major component of amino acids, proteins, and DNA.

Amino acids are the building blocks of proteins and without proteins plants cannot carry out biochemical reactions they need to survive.

Nitrogen is also a constituent of ATP (Adenosine Triphosphate), which allows cells to conserve and use the energy released in metabolism.

DNA is the genetic material that allows plants and animals to grow and reproduce.

Animals consume living or dead organic matters containing molecules of nitrogen for their metabolism, growth, and reproduction. (Deacon)

2.2.3.1 Photosynthesis in plants

The process of utilizing light energy in the presence of chlorophyll to convert carbon dioxide and water to form sugars is called photosynthesis. Nitrogen is the key component of chlorophyll by which plants utilize the sunlight and produce sugars from water and carbon dioxide.

2.2.4 Excessive Nitrogen; effects on water resources

Nitrogen is a vital component for all life. The deficiency of nitrogen limits the plant growth and reproduction. While the excess amount of it in water causes algae to grow faster which harm the quality of the water, food resources, and habitats. The algal bloom use up most of the oxygen and leave very little or not at all for fishes and other aquatic invertebrates to breathe resulting in their death decreasing animal and plant diversities. The wide spread algal bloom block sunlight to deeper waters

Toxins are generated by some algal blooms, which by any means (swimming, drinking water, fish consumption) come in contact to humans can be harmful. High concentration of nitrogen as nitrates in drinking water can be fatal to young infants and young livestock.

2.2.5 The Nitrogen Cycle

Nitrogen is abundantly available in atmosphere and sediments but neither plants nor animals can utilize it directly. It is a vital element for both plant and animal life. It is the basic component in all amino acids, proteins, and nucleic acids like DNA and RNA. Chlorophylls in plants use up nitrogen to carry out photosynthesis process. And animals fulfill their nitrogen demands by feeding on plants. The cycle in which nitrogen is converted into its different chemical forms through various biological and physical process within the biosphere is known as the nitrogen cycle.

Plants can uptake nitrogen only when it is incorporated in compounds like ammonium ions (NH_4^+), nitrate ions (NO_3^-), and urea ($(NH_2)_2CO$) for which they depend on a process called nitrogen fixation. The legumes and symbiotic bacteria from the legume's root nodules are the key players in this process. These nitrogen-fixing bacteria convert nitrogen in the soil to ammonia making it usable to the plants. In aquatic ecosystems, the nitrogen fixation is carried out by cyanobacteria.

When nitrogen is fixed, other bacteria convert it into nitrate. This process is known as nitrification. Nitrosomonas convert ammonia into nitrite in the first step and Nitrobacter convert nitrite into nitrate in the second step. The nitrate formed this way is ready to use for plants.

Further, varieties of microscopic bacteria, fungi, and other organisms reduce nitrites and nitrates to nitrogen and replenish the nitrogen content of atmosphere. This is known as denitrification.

The nitrogen cycle has following steps: (Harrison, 2003)

- Nitrogen Fixation
- Nitrification
- Assimilation
- Ammonification
- Denitrification

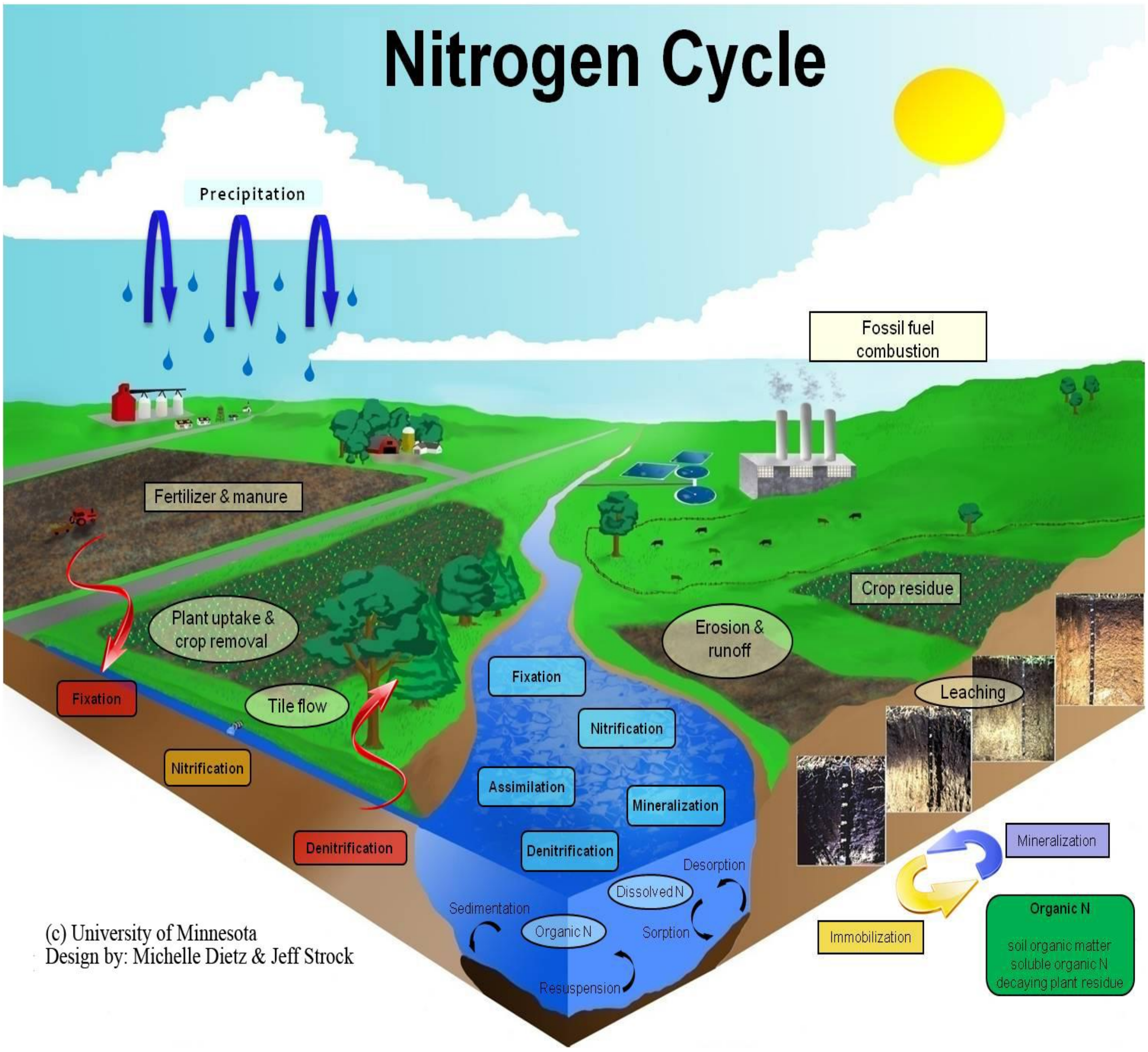

Figure 4: The Nitrogen Cycle (Dietz & Strock)

2.2.5.1 Nitrogen fixation

Nitrogen fixation is an anaerobic process of conversion of atmospheric nitrogen into ammonia. There are three different processes responsible for the nitrogen fixation in biosphere:

- Atmospheric fixation: Nitrogen molecule is inert. Therefore, a substantial amount of energy is needed in order to break it down. The enormous amount of energy released during lightning breaks down nitrogen molecule into atoms. These nitrogen atoms combine with oxygen in the atmosphere to form nitrogen oxides. When these nitrogen oxides dissolve in rain, they form nitrates and are carried to the earth.

- Biological fixation: Bacteria present in aquatic and terrestrial environments with the capability of producing a special enzyme known as dinitogenase reduce atmospheric nitrogen to ammonia. Ammonia then is quickly incorporated into protein and other organic nitrogen compounds. These microorganisms with the ability to fix nitrogen are called diazotrophs.

  Some microbes fix nitrogen independently and are called free-living. Biological Nitrogen fixation (BNF) requires energy.These non-photosynthetic free-living diazotrophs require chemical energy source while photosynthetic diazotrophs utililze sunlight. These diazotrophs contribute only a little amount of fixed nitrogen to the plants.

  Some microbes live in a symbiotic relationship with plants of the legume family (e.g. soybeans) and fix nitrogen in association. These microbes acquire the needed energy for BNF from the plant body they live in. The symbiosis occurs within nodules on the root and sometimes in stem.A significant amount of fixed nitrogen is provided to the plants by these bacteria.

- Industrial fixation: Industrially, atmospheric nitrogen and hydrogen are combined under great pressure, at a temperature of 600°C with the use of a catalyst to form ammonia. Ammonia can be used as fertilizer but most often it is processed further to make urea and ammonium nitrate.

2.2.5.2 Nitrification

In nitrification process, ammonia or ammonium ion is biologically oxidized to nitrite and then to nitrate. (Bartha, 1992)

First step: $NH4^{+} + 1\frac{1}{2}O_2 \rightarrow NO_2^{-} + 2H^{+} + H_2O$ (nitrite ion)

Second step: $NO_2^{-} + 1\frac{1}{2}O_2 \rightarrow NO_3^{-}$ (nitrate ion)

Nitrosomonas bacteria oxidize ammonia (NH_3) to nitrite (NO_2^-) and *Nitrobacter* oxidize nitrite to nitrate (NO_3^-). These bacteria are called nitrifying bacteria. Nitrification is an aerobic process.

Archeal microbes in soil and ocean also convert ammonia to nitrite. In addition to fixing atmospheric nitrogen, many legumes also convert nitrogen to nitrite and nitrate, which replenishes soil when they shed their leaves.

2.2.5.3 Assimilation

After nitrification, plants absorb the nitrate from their root hairs, which is then first reduced to nitrite ions and then ammonium ions. These nitrogen compounds are quickly incorporated into amino acids, nucleic acids, and chlorophyll. This process of incorporating nitrogen compounds formed through nitrification and nitrogen fixation to proteins and nucleic acids is known as assimilation. Animals assimilate their nitrogen by consuming plant tissues.

2.2.5.4 Ammonification

Ammonification is the process in nitrogen cycle where ammonia is formed in the soil by the decomposition of remains of plants and animals and the wastes produced by them. Microorganisms when feed on these plants and animals for their energy requirement produce ammonia as their byproduct. The ammonia is released to the environment.

2.2.5.5 Denitrification

Denitrification is the reduction of nitrates to gaseous nitrogen, which completes the nitrogen cycle. Denitrifying bacteria like *Pseudomonas* and *Clostridium* perform almost the reverse of the nitrogen-fixing bacteria. It is an anaerobic process.

2.2.6 Human Impacts on Nitrogen Cycle; Eutrophication on Aquatic Ecosystem

N is vital element to all living organisms in order to live, grow, and reproduce as it is the key component of DNA, RNA, and protein. It is abundant in the atmosphere and sediments bit most organisms cannot use the atmospheric nitrogen. Microorganisms drive all the different processes in nitrogen cycle providing usable nitrogen compounds for other living beings.

Many human activities like the application of nitrogen-based fertilizers, burning fossil fuels etc. have significant impact on the natural nitrogen cycle. The exponential increment in the industrial nitrogen fixation has drastically increased the global nitrogen fixation. N is a limiting nutrient.

The production of synthetic nitrogen fertilizers from industrial nitrogen fixation increased the agricultural productivity but it came with some consequences. Plants cannot utilize all the nitrogen fertilizer applied; some of it is washed off of the agricultural lands by rain, irrigation water, and flood to water bodies (surface water and ground water). Excess nitrogen in drinking water can lead to cancer and respiratory diseases in humans. The addition of excess amount of nitrogen in surface water results in nutrient over-enrichment known as eutrophication. (Harrison, 2003)

2.3 The Phosphorus Cycle

2.3.1 Phosphorus

Phosphorus is a chemical element with atomic number 15 and symbol P. Phosphorus cannot be found in a free state on earth, as it is highly reactive in nature. Phosphorus is a vital nutrient for all plants and animals. It plays a significant role in the growth and reproduction of plants. Phosphorus is a building block of some parts of human body and is present as a part of DNA molecules that store energy (ATP and ADP).

2.3.2 Phosphorus compounds

Unlike nitrogen, phosphorus is stored in soil and rocks in the form of phosphates on earth. Phosphorus moves in a cycle from rocks, water, soil sediments, and living organisms. Plants absorb phosphates in soil directly from their roots. Phosphates in rocks make its way to the soil and water as the rocks weather and erode. Plant growth depends on the availability of phosphate nutrients. The lack of phosphate results in slow growth of plants while excess amount of phosphate results in algal bloom. So any detectable amount of total phosphorus (above 0.025 mg/L) is an indication of pollution from fertilizers, manures, and other nutrient-rich wastes. (Schaechter, 2012)

2.3.3 Role of phosphorus in plants and animals

Phosphorus is a vital nutrient for all plants and animals. The phosphate ions from phosphorus are the building blocks of certain parts of human body like teeth and bones. These phosphates are critical parts of DNA molecules and energy storing molecules like ATP, ADP, and fat molecules of the cell membranes. Therefore, phosphorus is important in optimum growth and reproduction.

Plants absorb phosphorus through their roots mostly as the primary orthophosphate ion (H2PO4-). The absorbed phosphorus is either stored in the root or delivered to upper portions of the plant, which ultimately is integrated into organic compounds like DNA, ADP, and ATP. These ADP and ATP fulfill the high-energy phosphate demands for further essential processes to occur.

The addition of phosphorus in phosphorus-deprived soil advances the root development and winter hardiness and maturity. Thus, phosphorus is a fertilizer of choice among farmers all over the world. Although it enhances the plant growth, it does not increase the crop yield.

2.3.3.1 Photosynthesis in plants

The process of utilizing light energy in the presence of chlorophyll to convert carbon dioxide and water to form sugars is called photosynthesis. The sugar produced is captured by ATP and then is available for other reactions to occur as a source of energy. P is incorporated in these ATP from where it is moved throughout the plant for further reactions.

$$\boxed{6CO_2 + 6H_2O \Longrightarrow C_6H_{12}O_6 + 6CO_2}$$

2.3.4 Phosphorus; effects on water resources

Naturally, phosphorus is scarce in water. Phosphorus is a limiting nutrient for plants; low concentration of phosphorus limits the growth and reproduction of aquatic plants and/or algae. Adequacy of phosphorus enhances the plant growth and that is why farmers are tempted to use plenty of it as fertilizer. When excess amount of phosphorus is released in soil in the form of fertilizer and the plants cannot absorb all of it, phosphorus eventually ends up as sediments in lakes along with the run off. The increase in the phosphorus concentration in the water causes the microscopic algae to thrivewhich clouds the water making it difficult for the vegetation to receive sunlight and maintain the required oxygen level for suppoting life.

2.3.5 The Phosphorus Cycle

It is a biogeochemical cycle that shows the movement of phosphorus in the environment of the earth. Phosphorus is found in solid state for living organisms to use in the environment. The phosphorus cycle follows the following path.

- Weathering and erosion of rocks releases phosphorus into the water sources and soil.
- The phosphates released such way get absorbed by plants and transferred to the herbivores animals and then to the carnivore's animals.
- The phosphates finds its way back again to the soil through excretion and decomposition of plants and dead materials by microbes.
- The leaching of the soil and the run offs again carries away the phosphates to the water where algae and plants consume it.
- This is the natural way of phosphorus revolving around our ecosystem. But human activities cause a serious impact on the phosphorus cycle. (Schaechter, 2012)

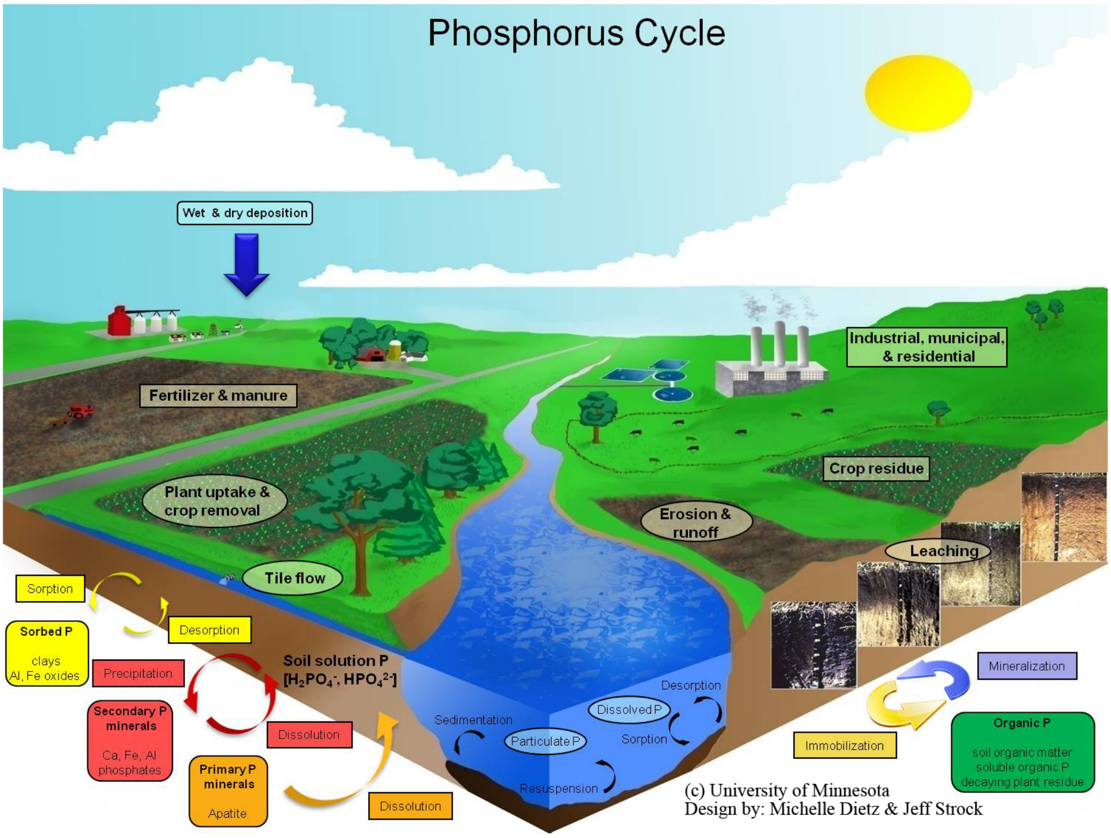

Figure 5: The Phosphorus Cycle (Dietz & Strock)

The deposition of phosphorus in the lakes, waterways, and other sources of water is mediated by the following ways:

2.3.5.1 Weathering

The exposure of the rocks to the atmosphere weathers them and causes to break down via different environmental processes. Weathering processes can be categorized into two categories; physical process and chemical process.

Physical weathering involves different processes like thermal expansion, pressure release, saltcrystal formation, freeze-thaw etc. causing deterioration of rock materials without changing the chemical composition of the parent material.

Chemical weathering involves various processes like dissolution, hydrolysis, hydration, and redox reactions by altering the composition of the parent material directly or indirectly.

The weathering of rocks release phosphate ions to the soil and then to the water sources. These are inorganic phosphates. Algae, plants, and animals consume these inorganic phosphates. The decomposition of dead plant and animal matters by the microbe releases phosphorus back to the soil.

2.3.5.2 Solubilization

Phosphorus is present in soil as inorganic salts like calcium phosphates ($CaPO_4$), iron phosphates ($FePO_4$) etc.; organic phosphates like phospholipids, nucleic acids etc. A huge percentage of inorganic phosphorus is insoluble as it is trapped in between clay layers in crystals and therefore is not readily available for plant use.

Different kinds of bacteria and fungi from the soil and rhizosphere are capable of solubilizing insoluble phosphates, which directly benefits them by providing the much-required usable phosphorus for their growth.

Various factors like moisture content and pH of the soil, weather conditions, particle size and solubility of phosphate form influences the solubilization process.

2.3.5.3 Mineralization

The decomposition of dead plant and animal matters contains a large amount of organic phosphorus in soil environment. The inability of the organic phosphorus to penetrate the cell membranes restricts its direct usability. For the plants to be able to use it, organic phosphorus first has to be mineralized to phosphates. Microbes consume this organic phosphorus and change it to orthophosphates. This process of microbial conversion of organic phosphorus to usable orthophosphates to plants is called mineralization.

2.3.5.4 Immobilization

Mineralization and immobilization occur simultaneously in soil environment. Immobilization is a reverse process to mineralization. It is referred as a process where the plant available phosphorus is removed from the soil environment and stored within living cells for a short period of time by the microbes to fulfill their own nutritional needs. Low phosphorus content in the pool causes the microbes to compete with plants for the phosphorus need. Upon the cell death, the process is rapidly reversible.

2.3.6 Human Impacts on Phosphorus Cycle: Eutrophication on Aquatic Ecosystem

Microbes have been maintaining and balancing the natural P cycle since millions of years. Plants use it for their growth, reproduce, die, and again liberate it to the environment. The cycle has been going on and on. But the human act influences the P cycle significantly and alters the microbial communities resulting in devastating ecological consequences.

Deforestation and mining of P for fertilizers and animal feeds has altered the P cycle globally.

The exposure of rocks and soil from the deforestation and mining escalates the rate of weathering and erosion resulting in a massive accumulation of P in its local aquatic ecosystems.

The use of synthetic P fertilizers in the agricultural practices is the other key cause of deposition of P in the aquatic ecosystem. Plant may not use all the phosphates from the fertilizer. So most of the nutrient is lost through the run off. In cold environment, a substantial amount of fertilizers applied to the frozen ground can be lost during the spring thaw. Sometimes the temptation and irrational over application of P fertilizers puts up extra amount of phosphates to the aquatic ecosystem. Sewage, when not treated properly or not treated at all adds up phosphates to the water sources. It is estimated that the increase in net P storage in terrestrial and aquatic ecosystem is at least 75% greater than preindustrial levels.

When the extra P from above mentioned human activities enters the water bodies where the natural P availability limits the production, substantial changes occur in the microbial community. The overenrichment of growth –limiting nutrient in the water enhances the excessive growth of phytoplankton commonly known as eutrophication.

3 METHOD

3.1 Sampling

3.1.1 Locations

The samples were collected on 12.08.2014 from the lake Huhmarjärvi. The day was sunnny and windy. All the safety measures were carried out and sampling was done in a proper manner. Samples were collected from lake Tervalampi on 20.08.2014. The weather was cloudy and windy on the sampling day. For water analysis, five samples were collected from each lake. The different sampling points with their coordinates are given below in the table.

Table 1: Sampling points and their coordinates for the lake Huhmarjärvi

Sampling points	Coordinates
H1	N60 °18.07 E24°22.20
H2	N60 °18.13 E24°22.56
H3	N60 °18.17 E24°22.54
H4	N60 °18.21 E24°23.23
H5	N/A

Table 2: Sampling points and their coordinates for the lake Tervalampi

Sampling points	Coordinates
T1	N60 °19.00 E24°25.04
T2	N60 °19.03 E24°24.41
T3	N60 °19.19 E24°24.51
T4	N60 °19.13 E24°24.57
T5	N60 °19.11 E24°25.16

Huhmarjärvi is situated in the coordinates 60°18'12"N   24°22'55"E

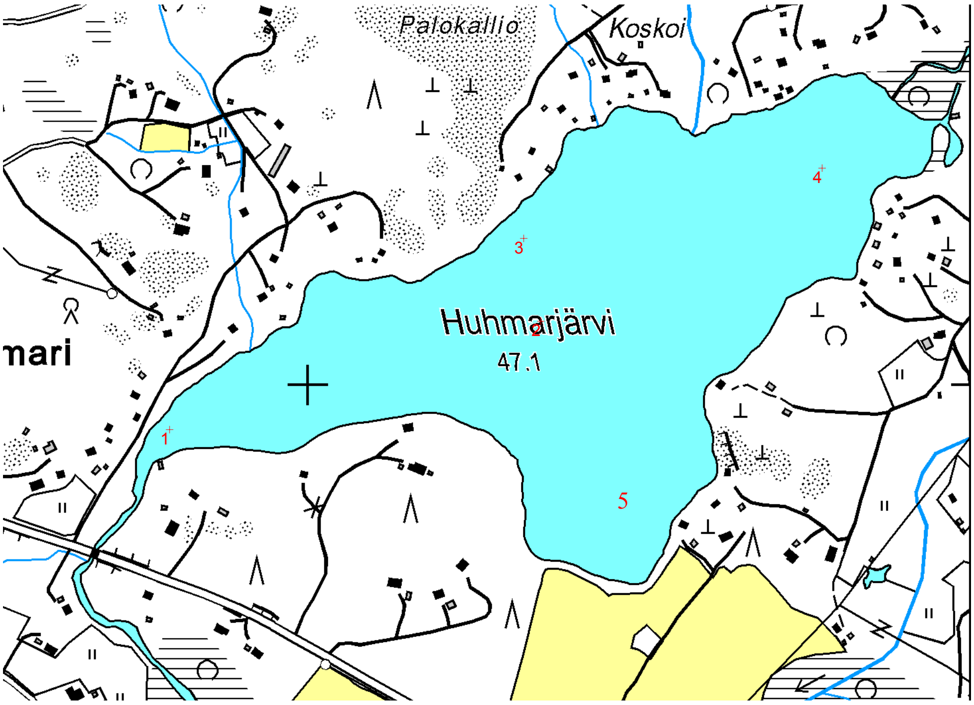

Figure 6: Sampling points of lake Huhmarjärvi

Tervalampi is situated in the coordinates 60°19'46.8"N   24°25'27.6"E.

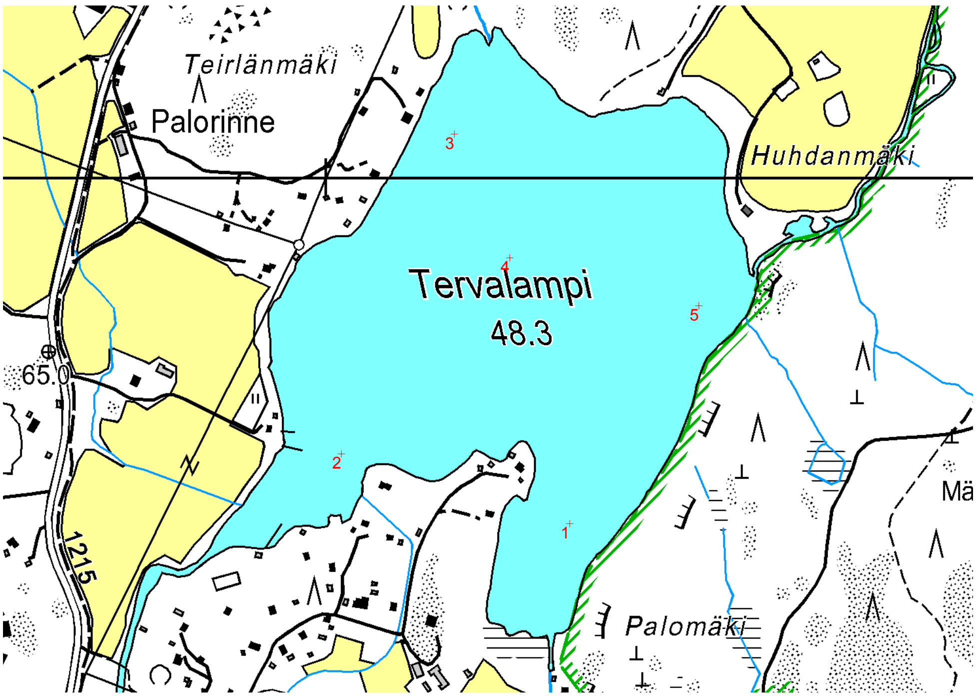

Figure 7: Sampling points of lake Tervelampi

3.1.2 Measuring Parameters

The parameters analyzed during this thesis project are listed below:

- Site Depth
- PH
- Temperature
- Conductivity
- Dissolved Oxygen
- Total Phosphorus content
- Total Nitrogen content

3.1.3 Equipment

Equipment used for collecting samples and conducting on-site analysis are given as follows:

- Sampling bottles
- Cabinet (a storage for sampling bottles)
- Sample collector
- Secchi Disk
- Dissolve Oxygen Sensor
- Thermometer
- Measuring tape
- Depth measuring meter
- Lab quest pro

3.1.4 Sampling procedures

Samples were collected directly from the mentioned locations with the help of a sample collector and the following precautionary methods were followed during sample collection in order to prevent intrusion of impurities in the sample.

- Rinsing the sampling bottle for at least 10 times with lake water for removal of any impurities in bottle
- Filling collected water into bottles and keeping the bottles airtight.
- Four parallel samples were taken from the located areas. Each sample bottles contained 0.5 l of sample water.

3.2 Onsite analysis

The following parameters were measured onsite:

- Depth
- Temperature
- Dissolved Oxygen
- PH
- Conductivity

3.2.1 Procedure

3.2.2 PH

pH meter was used while measuring the pH value of the lake water. The pH meter was dipped into the lake water and the value was noted.

The stable value was obtained after few seconds of inserting the pH meter into the water. The pH value was measured.

3.2.3 Dissolved Oxygen and temperature

Procedure: DO meter was used to measure the dissolved oxygen value and the temperature of the lake water. The DO meter was dipped into the lake water and the read bottom was pressed

Analysis: The stable value was obtained after few seconds of inserting the DO meter into the water. The dissolved oxygen value and temperature was measured.

3.2.4 Depth

Procedure: A rod tied with measuring meter was plunged into the lake.

Analysis**:** As soon as the bottom end of the rod touches the base of the lake vertically, the value in the measuring meter was noted which was at the surface level.

3.3 Laboratory analysis of the samples

The water samples waere analyzed for the total phosphorus concentration and total nitrogen concentration n the Environmental Engineering laboratory.

3.3.1 Equipment

The following equipment were required for laboratory analysis:

- Heating unit
- Nephelometer
- Hach/Lange Spectrophotometer DR 3900
- Total phosphorus
- Total Nitrogen
- Spectrophotometer

3.3.2 Procedures

For few of the process the measuring equipment were standards developed by Hach/Lange Spectrophotometer DR 3900.

Hach/Lange Spectrophotometer DR 3900 is a complex instrument that measures the absorbance of biomolecules within the visible and UV light spectrum. It is the simplest way to perform water analysis where the human error is minimized. (Hach, 2015)

Figure 8: Hach/Lange Spectrophotometer DR 3900 (Hach, 2015)

3.3.2.1 Phosphorous

Code: LCK 349

Range**:** 0.05-1.50 mg/l PO_4-P

Procedure**:** The sample bottle was taken out from the cooling cabinet and was kept in safe place to obtain the room temperature. The total phosphorous analyzing kit was taken, and the foil screwed on DosiCap Zip was carefully removed. As much as 2 ml of sample was pipetted into the cuvette and immediately the DosiCap Zip was screwed back and shaken firmly. The cuvette was heated in the thermostat for 60 min at 100 ^{0}C. After cooling the cuvette in ice-bath, 0.2 ml of Reagent B was pipetted in the cuvette and immediately the Reagent B was closed. A grey DosiCap C was screwed on the cuvette and inverted few times in order to dissolve the chemical present in the Dozicap C. The cuvette was left at room temperature for 10 minutes, and then the outside part of cuvette was cleaned thoroughly by soft tissue paper. The cuvette was evaluated in the Hach/Lange Spectrophotometer DR 3900 by inserting the cuvette in the spectrometer.

3.3.2.2 Total Nitrogen:

Code: LCK 138

Range: 1-16 mg/l TN_b

Procedure: 1.3 ml of sample, 1.3 ml of solution A and 1 tablet of chemical B was added in quick succession to a dry reaction tube and closed immediately without inverting. The mixture was heated immediately (Thermostat: 60 min at 100^oC). Then it was cooled down and 1 microcap C was added. The reaction tube was closed, inverted few times until the freeze-dried contents were fully removed from Microcap C and all the steaks were vanished. 0.5 ml-digested samples was slowly pipetted into the Cuvette test. 0.2 ml of solution D was slowly pipetted in the cuvette and closed immediately and inverted few times until no steaks were seen. After 15 minutes the outside part of cuvette was cleaned thoroughly and evaluated. The cuvette was evaluated in the Hach/Lange Spectrophotometer DR 3900 by inserting the cuvette in the spectrometer.

3.4 Risk assessment

3.4.1 Onsite safety

Some of the experiments were conducted on site and all members were aware of the onsite safety measures and precautions, which included use of life jacket, precautions while rowing a boat. All the activities were planned and done in-group, so all members were aware of each other situation.

3.4.2 Laboratory safety

Reagents that were used for analyzing the lake water contained different types of chemicals and microorganisms. Although analyzing is quick test, appropriate steps as mentioned in manual of test kit were followed to complete analysis successfully.

Reagents and chemicals used in the analysis kit are poisonous and corrosive in nature thus proper attention was required in handling analysis kit. Proper use of laboratory coats, glasses and gloves were required while handling the analysis kit and sample water.

Material Safety Data Sheet (MSDS) of chemicals were checked before performing the analysis of samples.

4 RESULTS AND DISCUSSION

A number of tests for certain parameters were carried out directly on the sampling locations. To carry out the laboratory tests for selected chemical contents, the samples were brought back to the Environmental Engineering laboratory of Helsinki Metropolia UAS.

4.1 Huhmarjärvi

The results for onsite analysis were as follows:

Table 3: Onsite analysis of lake Huhmarjärvi

Sample No.	Actual Depth (m)	Sample Depth (m)	Conductivity (µs/cm)	Temperature (°C)	Dissolved Oxygen (mg/l)	pH
1	2,6	1,3	111,9	23,5	6,92	7,33
2	3,7	1,75	120	23,3	7,54	7,55
3	2,75	1,5	110,9	23,3	6,12	7,46
4	3	1,5	111,1	23,5	8,14	8,96
5	3,45	1,75	116,4	23,7	8,86	8,78

The samples on different sampling points were taken from different depths, mostly in between 1m-2m where the temperature of the water was warm above 23°C. The DO measurements were found in between the range of 6-9 mg/l, which indicates a healthy range of DO for fresh water resource. Freshwater bodies have a low conductivity than marine waters but there is no set standard for conductivity of water. The conductivity was found to be pretty consistent throughout all the sampling points. Natural water bodies have a pH range of 6.5 to 8.5. All the samples had pH values well over 7, which shows the water is slightly basic.

The total phosphorus and total nitrogen tests were done in the Environmental Engineering laboratory of Helsinki Metropolia UAS.

Table 4: Laboratory analysis of lake Huhmarjärvi

Sample No.	Phosphorous (mg/l)	Nitrogen (mg/l)
1	0,056	2
2	0,058	1,59
3	0,061	1,50
4	0,069	0,070
5	0,171	2,70

Total phosphorus measures all form of dissolved and saturated phosphorus. The concentration of 0.2 mg/l of phosphorus is considered as a healthy amount of phosphorus in a natural body of water. Algae cannot grow and thrive beolw that value. The results obtained from the laboratory tests suggest the concentrations to be slightly over 0.02 mg/l.

Organic nitrogen is present in different forms like nitrite, nitrate and ammonia in water. The concentration of total nitrogen over 3 mg/l suggests the discharges from agricultural wastes which enhances the growth of algae and plants in the water. But the results from the laboratory suggests the total nitrogen level to be well below 3 mg/l on all sampling locations.

4.1.1 Water quality of Huhmarjärvi (1991 - 2015)

The lake water of Huhmarjärvi has been monitored since 1991- 2011. The oxygen level with respect to the lake's area has been at a good level but during winter of 2002/2003 the oxygen level dropped to almost no oxygen situation and continued for few years. Water quality study of August 2011 suggests the presence of green algae and the visual depth to be 0.9-1 m. However, the nutrient concentration in the lake is high and increasing. Surface water phosphorus concentration generally ranged from 40-80 µg/l. (Niinimäki & Niinimäki, 2011)

According to a study made by Länsi – Uudenmaan vesi ja ympäristö ry on August of 2015, the lake water temperatures was very warm at 22^0 C in mid – August. The oxygen level situation was fairly poor near the bottom ranging from 1.2 - 1.7 mg/l while near the surface it ranged above 129 mg/l. Green algae presence was detected and the lake water was turbid. The total nitrogen and total phosphorus ratio in surface water was less than 17. Since the N/P ratio >15, the lakes are phosphorus limited. (Sallmen, 2015)

In 2014, the water quality of lake Huhmarjärvi was analyzed during the thesis project in Environmental Engineering laboratory of Helsinki Metropolia University of Applied Sciences. The average concentration of total phosphorus and total nitrogen of lake Huhmarjärvi was found to be 84.6 µg/l and 1572 µg/l.

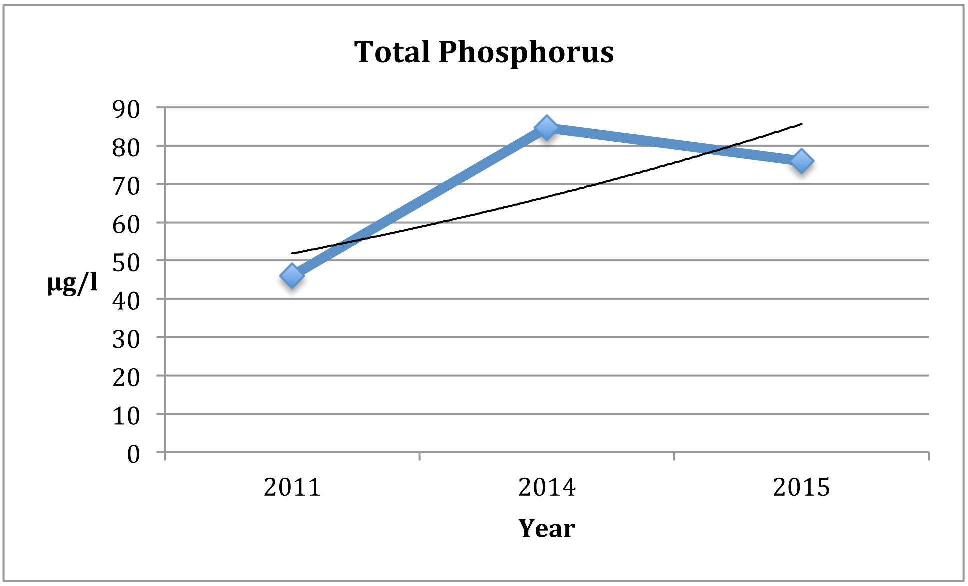

Figure 9: Total Phosphorus level in Huhmarjärvi from 2011 to 2015

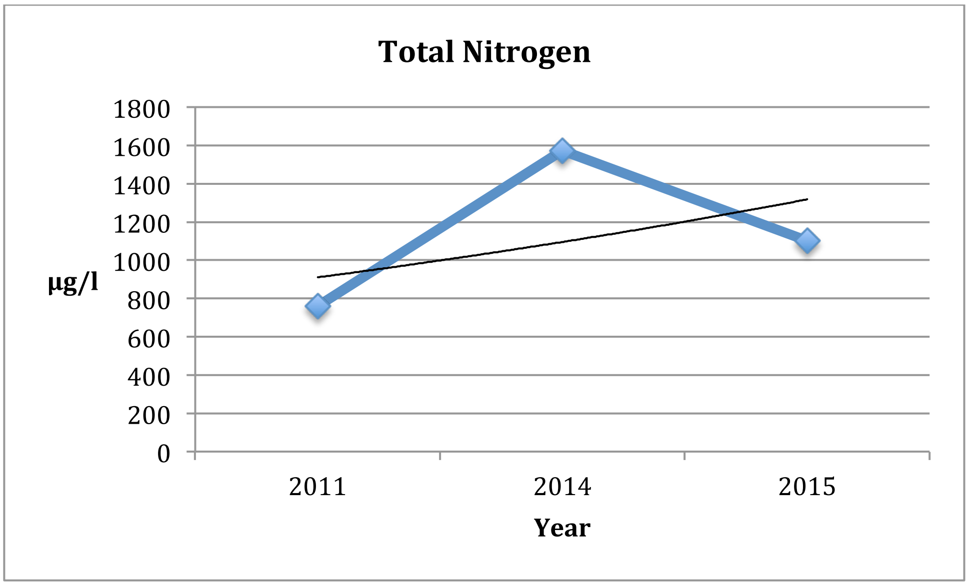

Figure 10: Total Nitrogen level in Huhmarjärvi from 2011 to 2015

4.2 Tervalampi

The results for onsite analysis were as follows:

Table 5: Onsite analysis of lake Tervelampi

Sample No.	Actual Depth (m)	Sample Depth (m)	Conductivity (µs/cm)	Temperature (°C)	Dissolved Oxygen (mg/l)	PH
1	2,0	1	113,9	18,5	6,95	7,02
2	1,69	0,80	104,8	18,5	7,42	6,97
3	2	1	109,3	18,4	7,60	7,48
4	3,40	2	111,7	18,3	7,71	7,36
5	3,32	1	107,7	18,8	7,01	7,04

The samples on different sampling points were taken from different depths, mostly in between 1m-2m where the temperature of the water was just above 18°C. The DO measurements were found in between the range of 6-8 mg/l, which indicates a healthy range of DO for fresh water resource. Freshwater bodies have a low conductivity than marine waters but there is no set standard for conductivity of water. The conductivity was found to be pretty consistent throughout all the sampling points. Natural water bodies have a pH range of 6.5 to 8.5. All the samples had pH values around 7, which shows the water is slightly basic. (Vertex water features, 2016)

The total phosphorus and total nitrogen tests were done in the Environmental Engineering laboratory of Helsinki Metropolia UAS.

Table 6: Laboratory analysis of lake Tervelampi

Sample No.	Phosphorous (mg/l)	Nitrogen (mg/l)
1	0,120	1,86
2	1,153	1,64
3	0,143	1,04
4	0123	1,20
5	0,132	1,53

Total phosphorus measures all form of dissolved and saturated phosphorus. The concentration of 0.2 mg/l of phosphorus is considered as a healthy amount of phosphorus in a natural body of water. Algae cannot grow and thrive beolw that value. The results obtained from the laboratory tests suggest the concentrations to be over 0.02 mg/l.

Organic nitrogen is present in different forms like nitrite, nitrate and ammonia in water. The concentration of total nitrogen over 3 mg/l suggests the discharges from agricultural wastes which enhances the growth of algae and plants in the water. But the results from the laboratory suggests the total nitrogen level to be well below 3 mg/l on all sampling locations.

4.2.1 Water quality of Tervalampi (1970 – 2015)

Tevalampi lake water quality has been monitored since 1970's. Surface water oxygen situation has been in fairly good situation except for the winters 2002/2003, when oxygen ran out almost completely. Also the oxygen level on near bottom has been good except for the winters of 2002/2003. Total phosphorus concentration in surface water range in between 40 – 100 µg/l. No clear trends can be observed but the nutrient concentration in the lake is high and increasing. (Niinimäki & Niinimäki, 2011)

According to a study made by Länsi – Uudenmaan vesi ja ympäristö ry on August of 2015, the lake water temperatures was very warm at 22^0 C in mid – August. The oxygen level situation was fairly poor near the bottom ranging from 1.2 - 1.7 mg/l. The total phosphorus concentration was 0.092 mg/l and the total nitrogen concentration was 1.3 mg/l. (Sallmen, 2015)

In 2014, the water quality of lake tervalampi was analyzed during the thesis project in Environmental Engineering laboratory of Helsinki Metropolia University of Applied Sciences. The average concentration of total phosphorus and total nitrogen of lake Tervalampi was found to be 334.2 µg/l and 1454 µg/l.

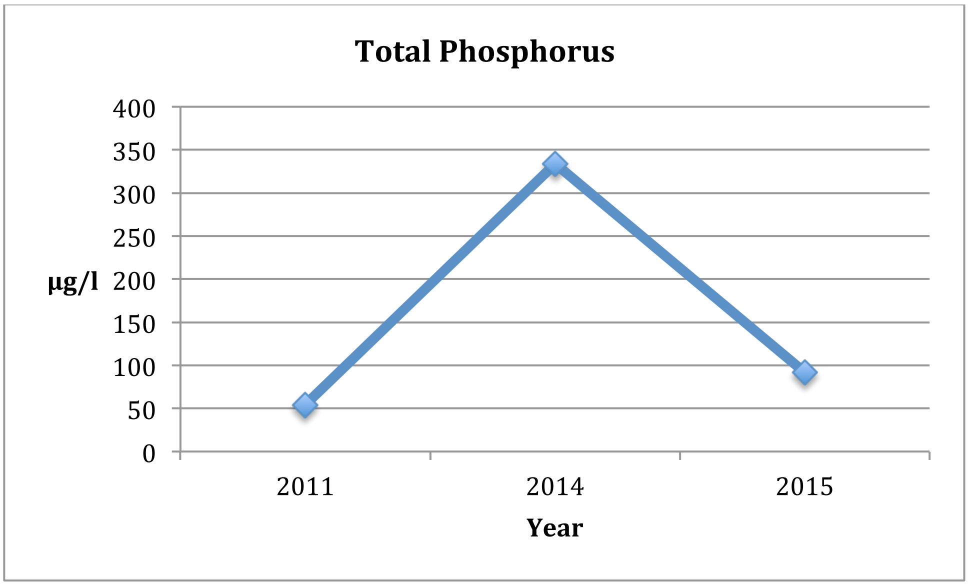

Figure 11 : Total Phosphorus level in Tervelampi from 2011 to 2015

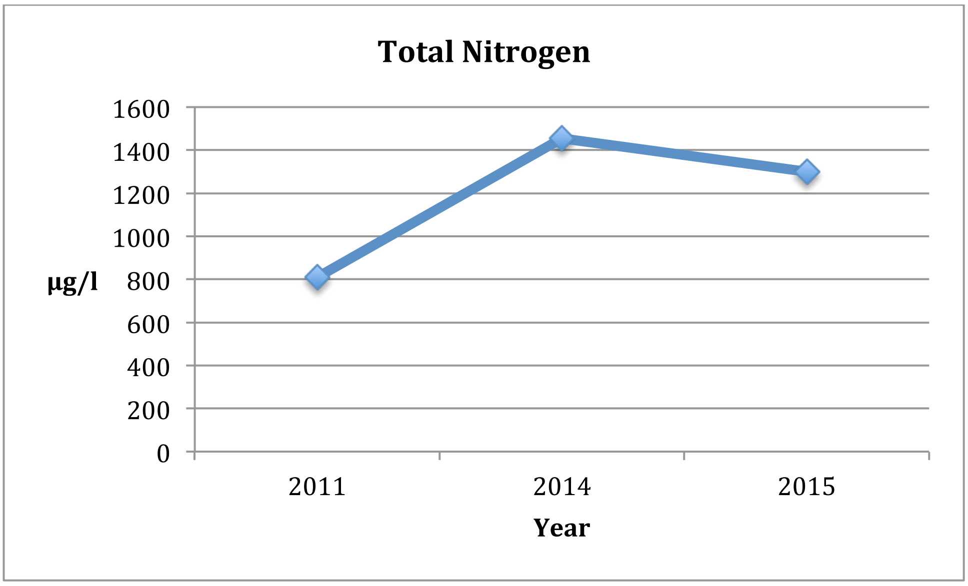

Figure 12 : Total Nitrogen level in Tervelampi from 2011 to 2015

5 CONCLUSION

The nutrient over enrichment of a water body causes eutrophication, which has numerous negative impacts on the aquatic ecosystem. Eutrophication occurs naturally too, but various human activities for example human settlements, industrialization, and agricultural practices has accelerated the plant and algal over growth.

The results from the tests conclude that the total nitrogen concentration in the lakes is healthy. However, the results obtained from the laboratory analysis suggest that the total phosphorus concentration of lake is higher than that of a healthy lake. The water from these lakes has been monitored for a long time now. The observations do not show a clear trend but the results clearly show that the lake waters are nutrient rich and the concentrations are increasing. Both the lakes are eutrophic. The excess amount of phosphorus in these lake waters must have been accumulated from the surrounding agricultural practices and human settlements for decades.

Proper measures should be applied in order to reduce the nutrient addition in the lakes from the agricultural practices and human settlements to prevent the lakes from turning into marshes and dried land. One of the most important measures to control eutrophication in an aquatic ecosystem is to stop the nutrients from entering the water bodies. Effective policies should be implemented in industrial and agricultural practices in order to limit their nutrient loading into the aquatic ecosystems. Less application of Phosphorus and Nitrogen fertilizers reduces the nutrient loading remarkably. Public awareness and environmental education is must to get better results.

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7 APPENDIX

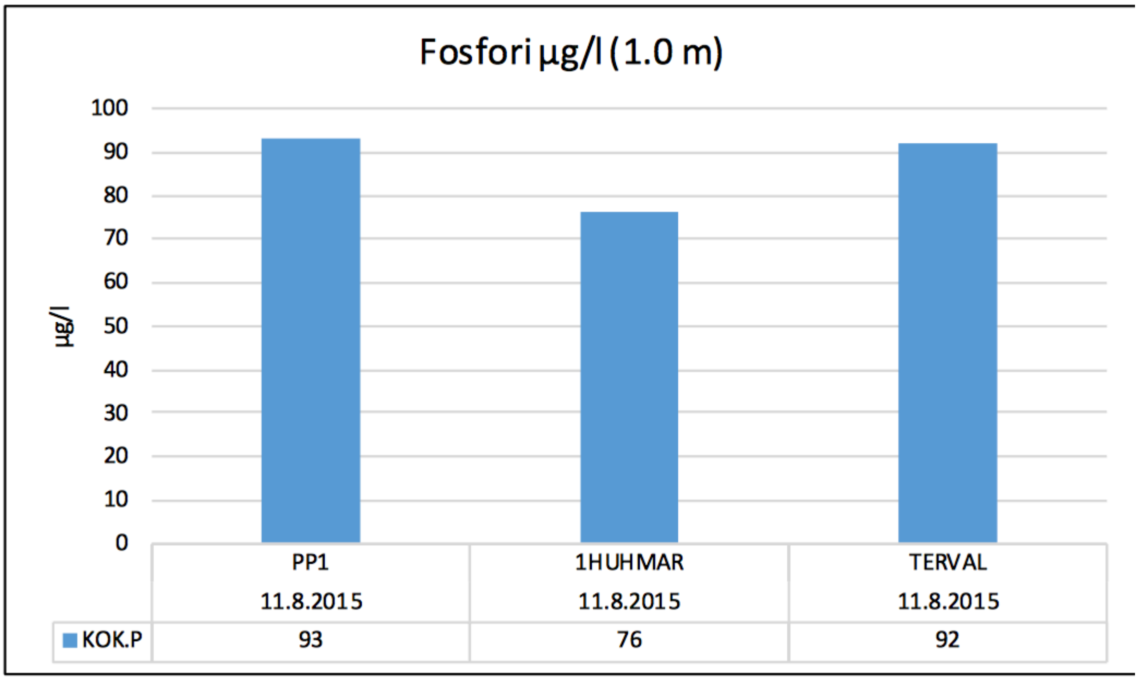

Figure 13: Phosphorus level in Huhmarjärvi and Tervalampi in 2015 (Sallmen, 2015)

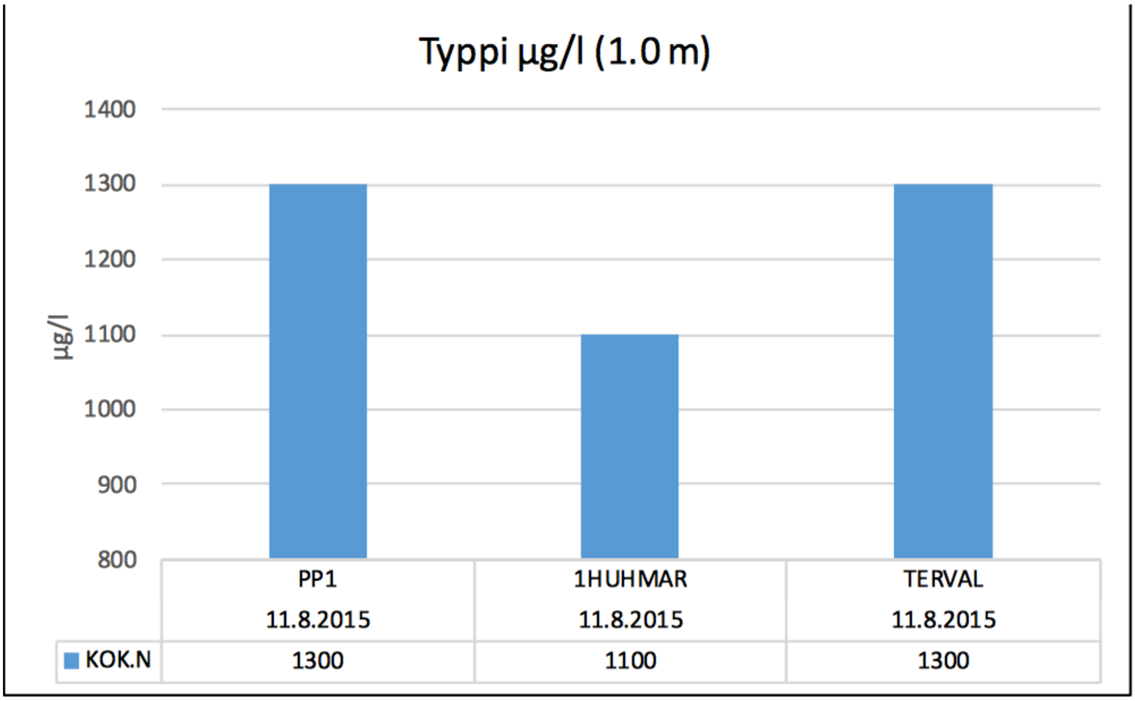

Figure 14: Nitrogen level in Huhmarjärvi and Tervalampi in 2015 (Sallmen, 2015)

Figure 15: Phosphorus level in Huhmarjärvi from 1991 to 2011 (Niinimäki & Niinimäki, 2011)

Figure 16: Nitrogen level in Huhmarjärvi from 1991 to 2011 (Niinimäki & Niinimäki, 2011)

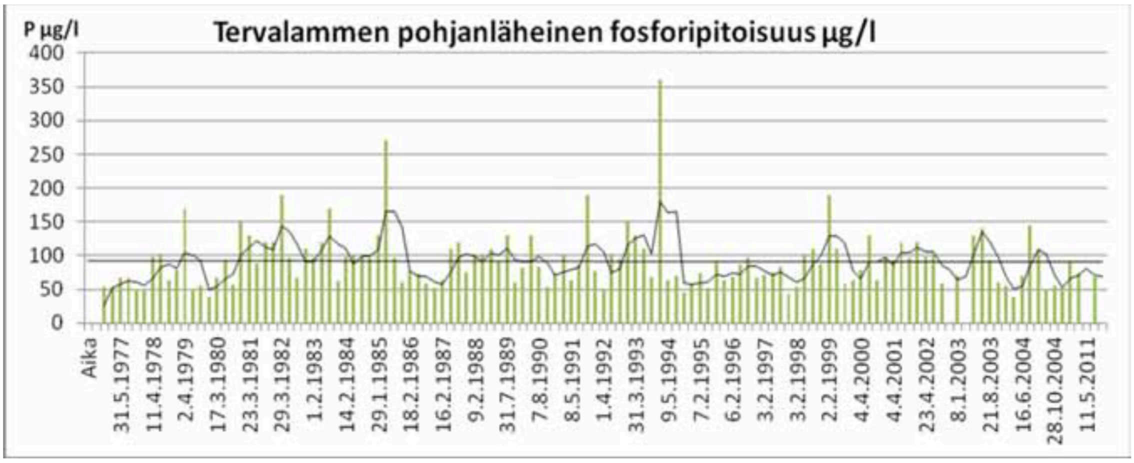

Figure 17: Phosphorus level in Tervalampi from 1991 to 2011 (Niinimäki & Niinimäki, 2011)

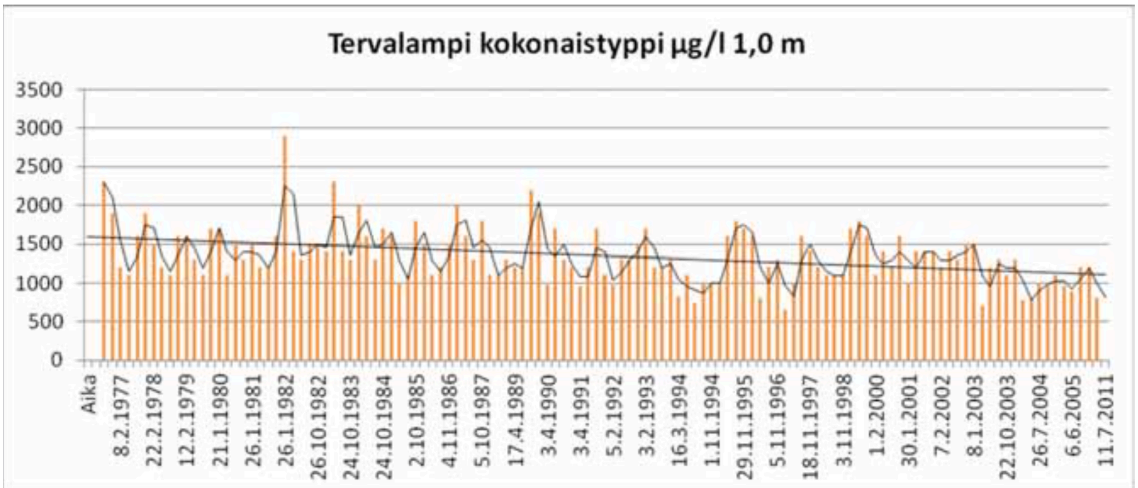

Figure 18: Nitrogen level in Tervalampi from 1991 to 2011 (Niinimäki & Niinimäki, 2011)

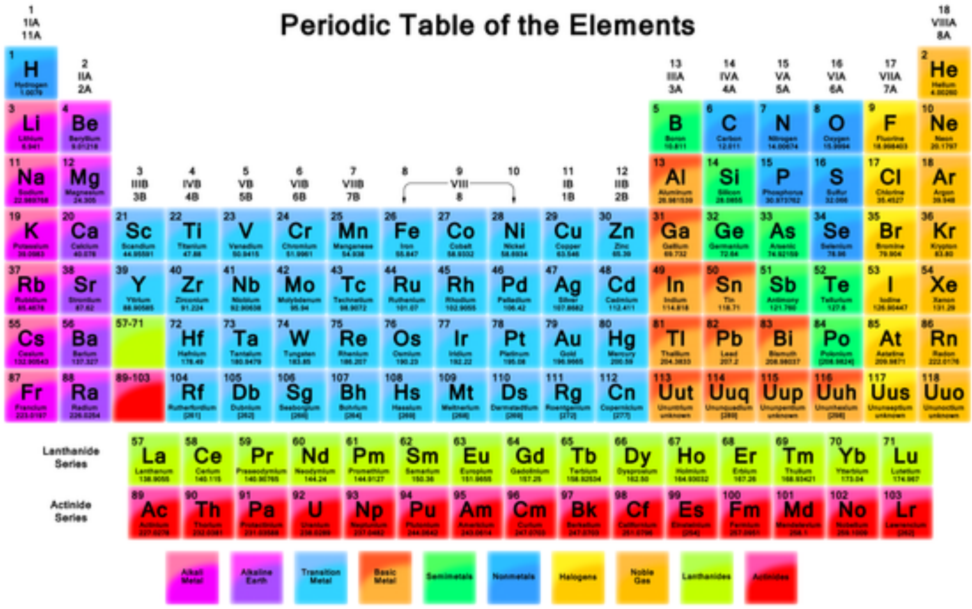

Figure 19: Periodic table of elements (About education, 2016)

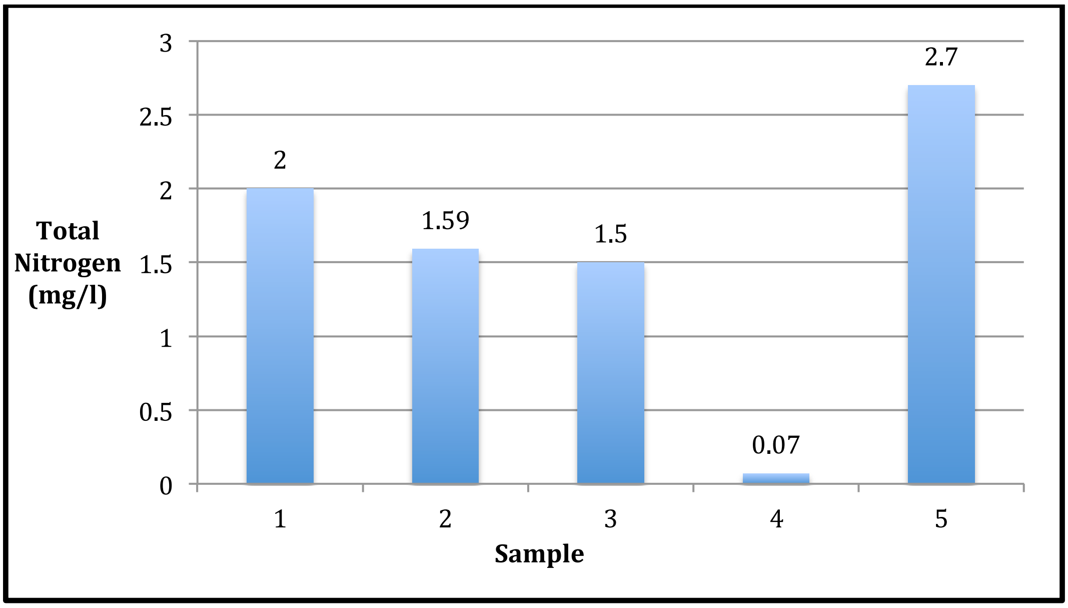

Figure 20: Nitrogen level in Huhmarjärvi in 2014

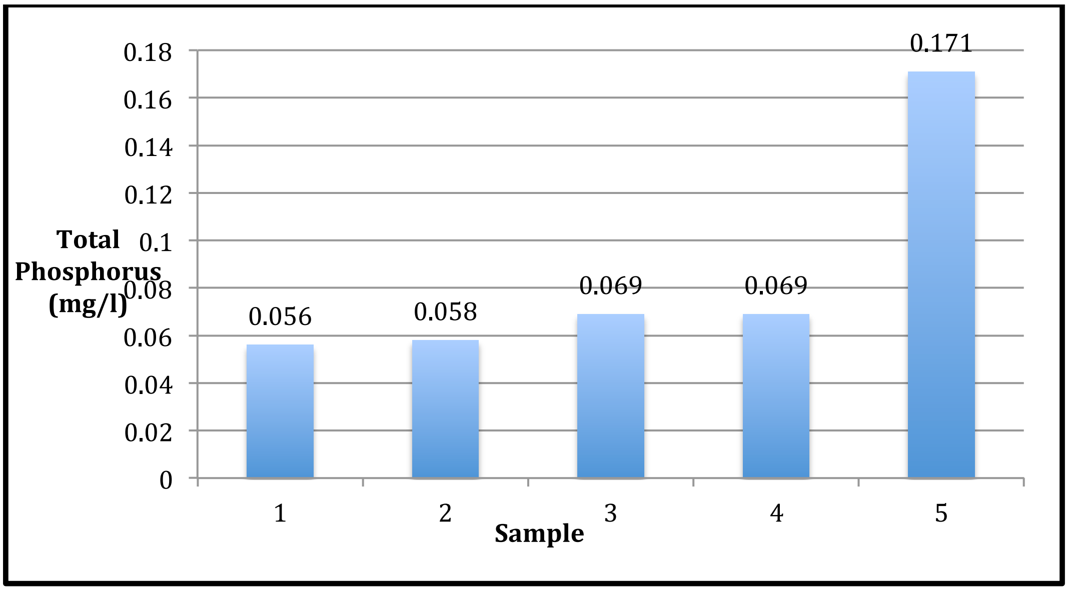

Figure 21: Phosphorus level in Huhmarjärvi in 2014

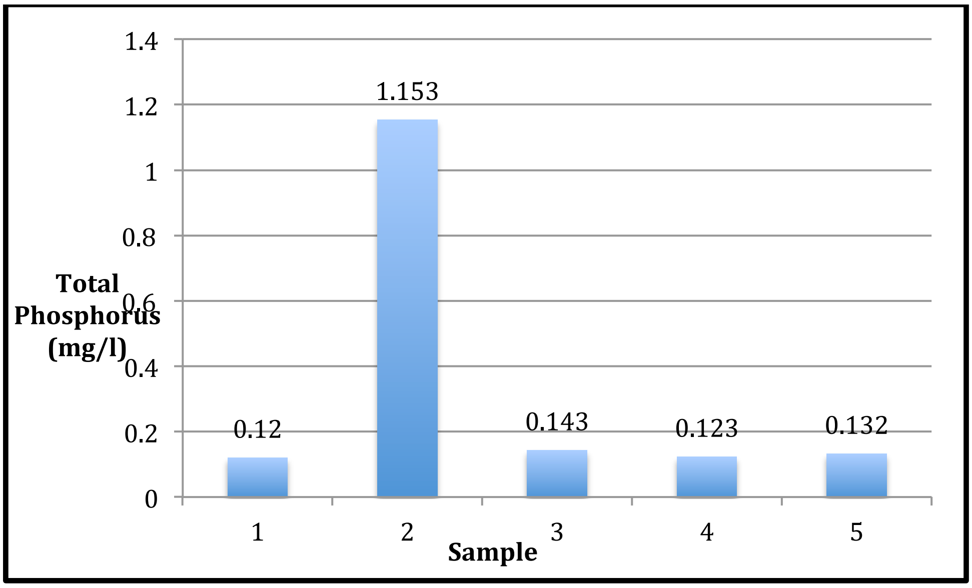

Figure 22: Phosphorus level in Tervalampi in 2014

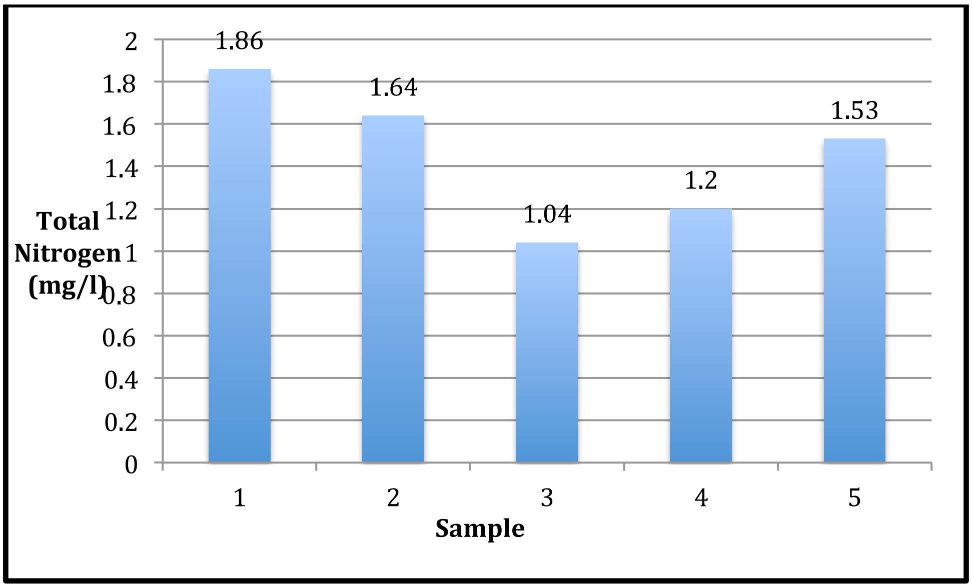

Figure 23: Nitrogen level in Tervalampi in 2014

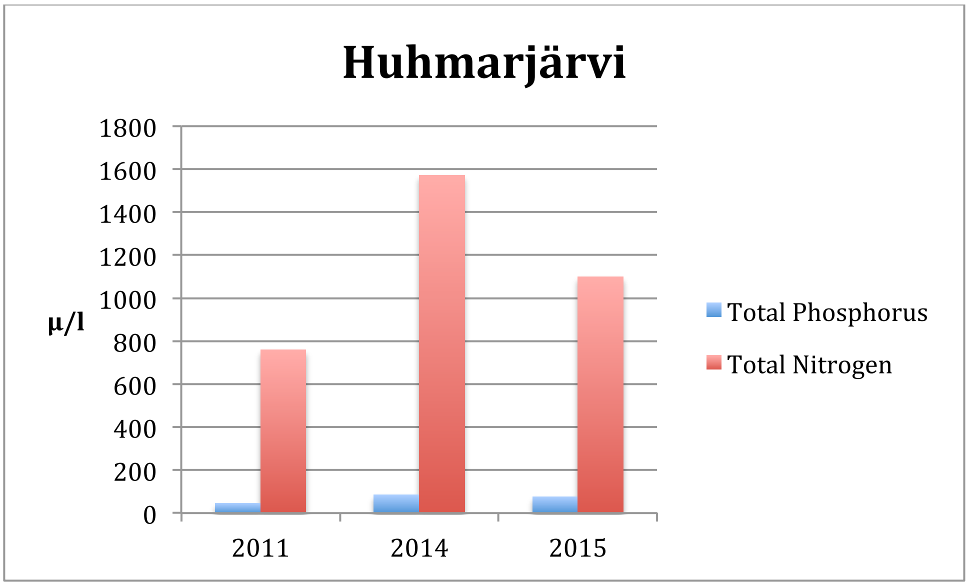

Figure 24: Total Phosphorus and Total Nitrogen from 2011, 2014, and 2015

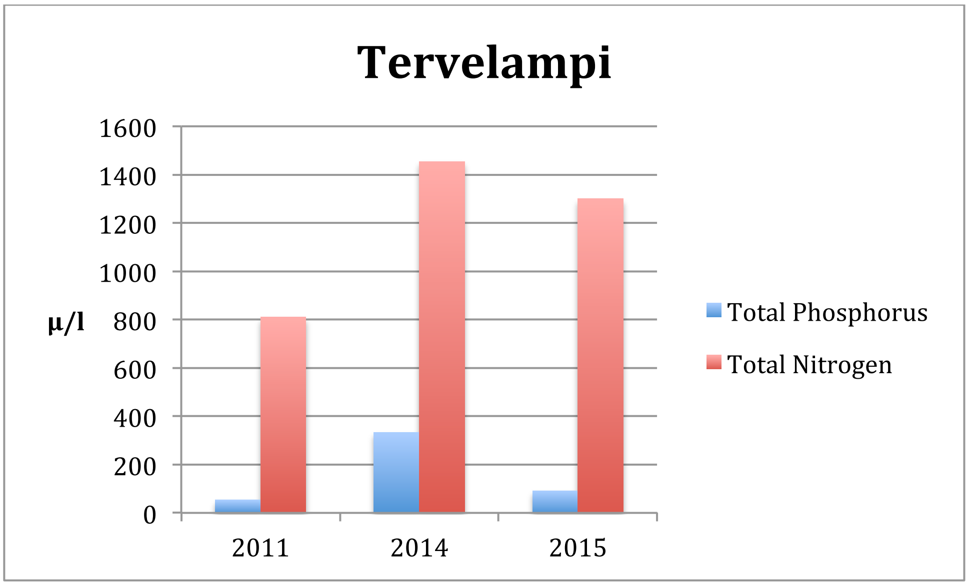

Figure 25: Total Phosphorus and Total Nitrogen from 2011, 2014, and 2015